# Synthesizing Artificial Electromagnetic Properties Utilizing Additive Manufacturing

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Printable inks have been developed with tunable permittivity, conductivity, and magnetic properties. In conjunction with semi-automated screen printing and micro-dispensing techniques, these inks allow for the creation of a wide range of artificial electromagnetic surfaces and structures. The applications of these printable materials includes, but is not limited to, novel antenna substrates, radar absorbing structures, radomes and frequency selective surfaces, and many others. These inks were fabricated by suspending particles in low loss structural grade resins, and tuned by varying the volume fraction of particles to resin. Previous research and development into custom printable materials has focused primarily on either their electromagnetic or structural properties, often producing inks which are structurally insufficient or electromagnetically incompatible. The ink systems have been designed to allow for the additive manufacture of standalone parts/surfaces as well as to be compatible with structural grade composites. In the case of the magnetically tunable inks, magnetodielectric nano-particles (MD-NP) were synthesized in-house for inclusion within the ink. The electromagnetic properties of the MD-NP are dependent on the composition of magnetic species, physical attributes, such as size and geometry, and conductivity. The inks were characterized at a wide range of loading volumes and frequencies using a vector network analyzer (VNA). For each ink a model, using an effective medium approximation method, predicting the tunable property based upon loading fraction was developed. Structures with regionally varying loss, permittivity, and permeability were designed and additively manufactured using a combination of screen printing and nScrypt$^{TM}$ micro-dispensing systems. The completed structures were then tested and the results were compared to simulated responses.